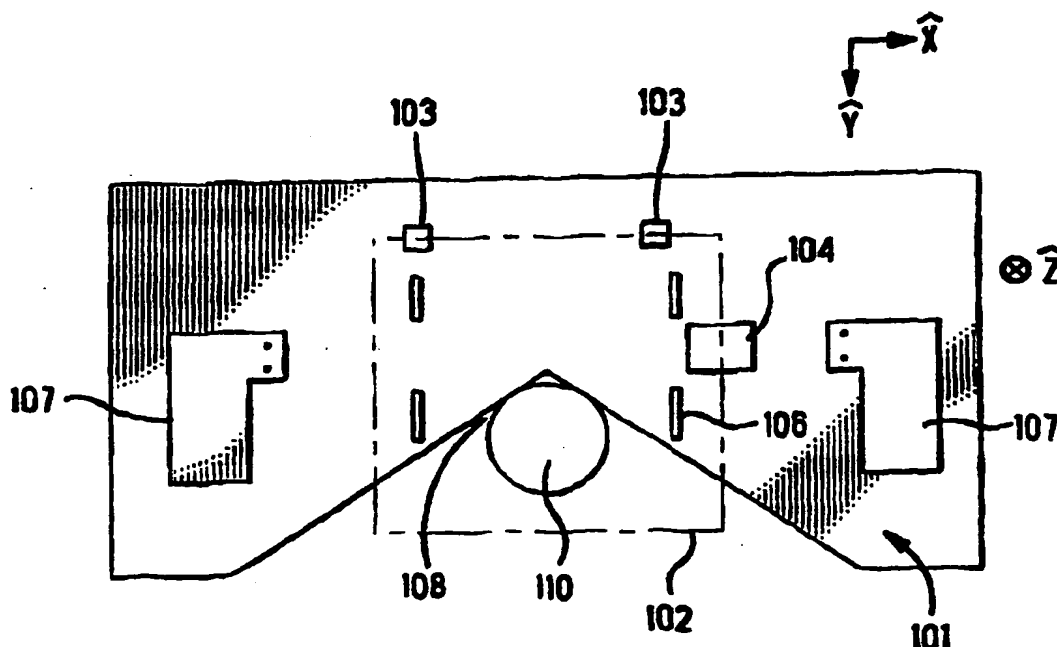


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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(21) International Application Number: PCT/US96/10996 (22) International Filing Date: 27 June 1996 (27.06.96) (30) Priority Data: 60/000,777 30 June 1995 (30.06.95) US (71) Applicant: THE WHITAKER CORPORATION [US/US]; Suite 450, 4550 New Linden Hill Road, Wilmington, DE 19808 (US). (72) Inventors: BOUDREAU, Robert, Addison; 1270 Stonegate Drive, Hummelstown, PA 17036 (US). BOWEN, Terry, Patrick; 85 York Hill Road, Etters, PA 17319 (US). HAN, Hongtao; 22 Cumberland Estate Drive, Mechanicsburg, PA 17055 (US). (74) Agents: FRANCOS, William, S. et al.; The Whitaker Corporation, Suite 450, 4550 New Linden Hill Road, Wilmington, DE 19808 (US).		(81) Designated States: CN, JP, KR, SG, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report.</i>

(54) Title: PASSIVE ALIGNMENT FRAME USING MONOCRYSTALLINE MATERIAL**(57) Abstract**

The present invention relates to a simple but fundamentally different way of aligning optical fibres (110) and devices (102) on monocrystalline material. To this end, a passive alignment frame (101) has etched surface for receiving an optical fiber (110) for attachment therein. Also disposed on the passive alignment frame (101) are alignment pedestals (103, 104) and standoffs (106) that are formed on the frame (101) by reactive ion etching. The pedestals (103, 104) allow for ready and accurate placement and bonding of the device (102) to be coupled to the fiber (110). The device (102) and the fiber (110) are aligned and coupled passively.

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Passive Alignment Frame Using Monocrystalline Material

5 The invention of the present disclosure relates to
a collinear passive alignment apparatus for aligning
both active and passive optical devices on a
monocrystalline material.

10 The use of monocrystalline materials has enabled
the passive alignment of optical devices to optical
fiber for optical communication. The use of such
materials to replace the requirements for active device
alignment has great potential to effect the low cost,
15 large production of optical links that have application
to Fiber to the Home (FTTH) and Fiber to the Office
(FTTO). Accordingly, the recent past has seen a great
deal of interest and inventive activity in the
development of passive alignment based on the use of
20 monocrystalline materials. A common material for such
use is monocrystalline silicon, as its crystalline
properties are well known in the art. Techniques for
etching silicon to expose well-defined crystalline
planes are well known.

25

One of the preferred set of devices in the optical
communication technology is the surface emitting and
detecting device. To this end, the use of devices such
as Vertical Cavity Surface Emitting Lasers (VCSELS) and
30 photodetectors (such as PIN photodiodes) that have the

photosensitive surface to receive or emit light on the top surface has required a great deal of modification to effect the alignment of the device to an optical fiber. In general, to effect the alignment between the device
5 and the fiber using a silicon optical bench, it is required to have the device on a different plane than the fiber, with the light being communicated therebetween by a reflective surface. While such technology has its merits in allowing passive alignment
10 to some extent, it is nonetheless required that the device be actively aligned into position so that light is properly reflected by the reflective surface. Furthermore, the use of a reflective surface decreases coupling efficiency, since there are intrinsic losses
15 incurred at each optical surface through dispersive effects. Accordingly, a more efficient system would allow for in-line coupling between the fiber and the device.

20 The use of silicon waferboard technology to effect the coupling between the device and the fiber in a co-linear fashion is well known. It is known to use two pieces of monocrystalline material as mounting members that have etched therein detents in complimentary

25 locations on each of the pieces of the mounting members.

These detents receive microspheres to effect the alignment of the mounting members to effect the coupling of the device to the fiber. While the reference does disclose the use of other types of alignment fiducials,
30 there are two substantive drawbacks to the invention

disclosed in this reference. To effect alignment, there is required a separate member for holding the device to be coupled to the fiber, and another member to hold the optical fiber. Furthermore, the alignment fiducials are
5 separated piece parts that are placed between the waferboard holding the fiber and the waferboard holding the device.

As can be readily appreciated from a study of the disclosure of this reference, the alignment fiducials
10 are an additional processing step requiring additional parts to effect alignment. Furthermore, the alignment fiducials of this reference are a potential source of misplacement and thereby misalignment of the members. Accordingly, what is needed is an apparatus that allows
15 for direct attachment of the optical fiber and the device to a single alignment member. Furthermore, what is needed is an apparatus that enables passive alignment via alignment pedestals and standoffs that are integrally formed from and on the single alignment
20 member. The alignment therebetween is thereby made simply and effectively at a lower cost in manufacture.

The present invention relates to a simple but fundamentally different way of aligning optical fibers
25 and devices on monocrystalline material. To this end, a passive alignment frame has an etched surface for receiving an optical fiber for attachment therein. Also disposed on the passive alignment frame are alignment pedestals and standoffs that are formed on the frame by
30 reactive ion etching. The pedestals allow for ready and

accurate placement and bonding of the device to be coupled to the fiber. The device and the fiber are aligned and coupled passively. In the preferred embodiment shown in Figure 2, the device and the fiber
5 are bonded to the passive alignment frame which is then readily packaged without substantial limitation. In another embodiment, the fiber is bonded first to a groove disposed on a substrate, and the surface emitting/receiving device is mounted on the passive
10 alignment frame which is then mounted on the substrate and passively aligned to the fiber. Metallization is also provided on the passive alignment member (PAM) for electrical connection between the device and external circuitry.

15

It is an object of the present invention to passively align an optical fiber with a surface emitting or receiving device in a collinear fashion.

20 It is a further object of the present invention that the fiber and the device are bonded to a passive alignment member and passively aligned, forming an integral unit.

25 It is a feature of the present invention to effect the collinear alignment of the optical device to the surface emitting or receiving device by the use of a single passive alignment member made of monocrystalline material selectively etched to effect the passive
30 alignment of an optical device to an optical fiber.

It is a further feature of the present invention that the proper placement of the device to effect accurate passive alignment is effected by pedestals that
5 are integrally formed from the single passive alignment member.

It is a further feature of the present invention that the selectively etched alignment pedestals are
10 placed to efficiently locate the surface emitting/detecting optical device to two degrees of freedom, with the passive alignment member locating the third degree of freedom.

15 It is an advantage of the present invention that the passive alignment members can be fabricated in large quantity and simultaneously from a single wafer by simultaneous processing techniques.

20 Invention will now be described by way of example with reference to the accompanying drawings which:

Figure 1 is an end view of the passive alignment member (PAM) with the optical device mounted on a front
25 surface, and the optical fiber mounted in a groove received from the rear surface of the PAM.

Figure 2 is a perspective view of the PAM shown in endview in Figure 1 having the device mounted thereon.

30

Figures 3 and 4 are perspective views of a single fiber-device coupling an alternative embodiment of the present invention.

5 Figure 5 is an endview of a section of a wafer having been processed by the present invention to fabricate multiple single PAM's.

Figure 6 shows the placement of the fiber in the
10 PAM for single fiber application.

Figure 7 is a side view of the single device PAM mounted in the groove of the substrate with the fiber mounted therein.

15

Figures 8 and 9 shows a perspective view of the single PAM having multiple fibers and multiple devices mounted thereon for coupling, with the PAM and fiber mounted on a substrate.

20 Figure 10 is an endview of the multiple device/multiple fiber PAM.

Figure 11 is an endview of a section of wafer processed to produce a quantity of multiple
25 fiber/multiple device PAM's.

Turning to Figure 1, we see an end view of the passive alignment member (PAM) 101 having disposed thereon an optical device 102 and an optical fiber 110
30 disposed therein(shown in outline form). There is also

shown in Figure 1, the forward alignment pedestals 103, and the side alignment pedestals 104 which enable the accurate placement of the device 102. The device 102 is application driven, and is envisioned to be a VCSEL, a
5 p-i-n photodiode or a hologram used for various applications such as focusing or wavelength division multiplexing. The particular device utilized need only be a surface emitting or receiving device. Finally, the metalization for effecting electrical connection 107 as
10 well as the optional alignment standoffs 106 are shown. The apparatus in final mounted form is shown in Figures 3 and 4 in perspective view.

The basic essence of the present invention is that
15 the surface emitting/receiving device 102 can be passively aligned to the fiber to submicron precision using the inside edges of the passive alignment member. Turning to Figures 1 and 2, we see the preferred embodiment of the present invention. To this end, the
20 alignment of the device 102 is effected by the alignment pedestals 103 and 104. As can be seen in Figure 2, the device 102 is etched by RIE to have notches to receive the pedestals. In this way the device is precisely positioned with respect to the groove 108 of the PAM
25 101. Thereafter, the fiber 110 is seated in the groove 108 and the device 102 is aligned passively to the fiber 110. The device is then bonded to the PAM by solder reflow, and the vertical standoffs 106 are used optionally in cases where solder on the device would
30 impede its emission/reception of light. The geometry of

the PAM having the fiber inserted therein and the device 102 missing is as shown in Figure 6.

In an alternative embodiment shown in Figures 3 and 4, the optical fiber 110 is shown mounted in a v-groove (not shown) that is etched by standard technique in the monocrystalline material that forms the substrate 302. Preferably, the substrate is made 100 Si and is etched by wet etching techniques as is discussed in the reference to North, et al. discussed *supra*. The PAM 101 is mounted in a cavity 303 in the substrate. This cavity is formed by diamond saw cutting in the substrate in a perpendicular fashion to the direction of the v-shaped groove that holds the fiber 110. Finally, the electrical connections for making contact between the device 102 and external electronics (not shown) is through the metalization 304 via metalization 107. As can be readily appreciated from a study of Figure 6, the fiber 110 is readily aligned in the PAM. To be clear, the fiber is bonded in the v-groove on the substrate. The fiber is thus placed in a well determined relationship with the groove 303, and thereafter the PAM is mounted in a well determined relationship in the groove, seating the fiber in its groove 108. The device is thereby passively aligned to the fiber. In order to create the final assembly linking the device 102 to the fiber for communication, the fiber 110 is bonded to the v-groove as is shown in Figures 3, 4 and 7. The bonding can be effected by soldering or other techniques such as electrostatic bonding techniques, or by solder

techniques. Finally, it is important to note that in addition to these bonding techniques, adhesives such as commercial are possible as bonding agents, and that all of the bonding techniques mentioned above are useful in bonding the fiber to the PAM as well as the substrate. The silicon substrate has a saw cut groove in the surface as shown at 303. The PAM having the device 102 mounted thereon are placed in the groove 303 and the fiber 110 then fits through the v-groove 108 effected as described above. This is shown clearly in Figure 6. The fiber is thereby passively aligned to the device 102. The PAM 101 may then be readily bonded to the groove 303 by presolder in the groove. Solder may also be placed on the contact areas 107 and 304 to enable electrical connection following reflow between the PAM and the silicon waferboard via the groove 303.

The steps of manufacturing the device is discussed presently. Turning now to Figure 5, we see the etched diamond shaped holes in quantity on a selected section of a wafer. The individual PAM's are then diced from the wafer. To this end, the wafer is preferably a monocrystalline Si wafer having a 110 plane on its top surface. This planar direction is chosen for purely illustrative purposes and it is understood that other planar orientations at variance with that chosen are within the purview of the skilled artisan and intended to be encompassed in the instant invention. To effect the structure shown, the diamond shaped holes are etched through the wafer by wet etching as described in the

North, et al. reference. The side and forward pedestals, 103 and 104 respectively, as well as the standoffs 106 are formed by reactive ion etching (RIE).

Details of RIE techniques can be found in
5 *Optoelectronic Integration: Physics, Technology and Applications*, Chapter 4, p. 113-119, Kluwer Academic Publishers, 1994, the disclosure of which is specifically incorporated herein by reference. In production, the features made by RIE are effected first,
10 then a mask such as SiN_x which acts as a mask as well as a protective layer for the features etched by RIE. A photoresist is applied thereto the surface and the holes 501 are formed by revealing the preferred crystalline planes through the wet etching technique. Finally, the
15 metallization patterns 107 are placed on the wafer by vacuum evaporation, sputtering or plating of conductive metals, preferably gold. At this point, the device 102 is mounted and passively aligned to the alignment features 103 and 104 and thereafter diebonded using a
20 passive alignment diebonder. Thereafter the individual PAM's having the devices 102 mounted thereon are diced from the wafer by the use of a diamond saw.

The vertical standoffs 106 have particular
25 application in the alignment when a VCSEL is the preferred device 102. To this end, in practice the fiber is fixed in position on the substrate 302 as described above, and the VCSEL is fixed in the x and y directions (assuming an orthogonal coordinate system) by
30 the use of the side and forward pedestals. The height

of the VCSEL in the z direction is carefully placed by the standoffs 106, as the VCSEL is bonded to the PAM with its epitaxial layer facing the fiber 110 (epi-side down), and as described above, the standoffs further
5 have the inherent benefit to prevent solder from interfering with device emission/reception of light.

The invention having been described for a single PAM coupling a single fiber to a single surface
10 emitting/detecting device, we now turn to the applicability and manufacture of an embodiment in which the PAM is to effect the alignment of an array of fibers and devices. This embodiment is shown in Figures 8-11.

Figures 8 and 9 are a perspective and top view of an
15 array link. To this end, a PAM 801 is disposed in groove 802 saw cut into the silicon substrate having preferably a 100 crystalline on its top surface wherein v-grooves are etched for receipt of fibers 805. The fibers are thereby aligned to an array of surface
20 emitting/detecting devices 804. The processes and techniques for effecting the forward and side alignment pedestals and standoffs as well as the etching of the PAM are identical to that described for a single fiber/PAM/device as described above. The PAM 801 is
25 shown on endview in Figure 10, having forward and side alignment pedestals 901 and 902, respectively, as well as optional standoffs 904. The metallization 905 is effected as described above. Again, in large scale production, the PAM is fabricated on a wafer of (110)
30 crystalline Si as is shown in Figure 11, and the

technique for the fabrication of the PAM, the mounting of the devices 804 and the separating of the individual array PAM are effected in an identical procedure as described above for a single PAM. Figure 12 and 13 show the multiple fiber/multiple device configuration with the device 122 and fibers 123 mounted on the PAM 121 by forming an integral unit by techniques described for the single device/single fiber PAM as shown in Figures 1 and 2.

10

The invention having been described to be readily understood by the artisan skill, it can be appreciated that variations in material and devices to effect the passive alignment members are considered within the purview of the ordinary skilled artisan. For example, it is clearly considered within the purview of the present invention that in a multiple device/multiple fiber PAM can be used as a transeciver. Such are considered within the scope if the invention.

20

1. An apparatus for aligning an optoelectronic device to an optical fiber in a colinear fashion, having a groove for placement of said fiber and a surface for mounting said device, characterized in that:

5 said groove and said surface are disposed on a single alignment frame.

2. An apparatus as recited in claim 1 further characterized in that:

10 said frame has integral alignment members disposed on said surface.

3. An apparatus as recited in claim 1 further characterized in that:

said frame is a monocrystalline material.

15 4. An apparatus as recited in claim 2 further characterized in that:

said groove has sidewalls in well defined crystallographic planes.

5. An apparatus as recited in claim 2 further characterized in that:

20 said integral alignment members are pedestals and standoffs.

6. An apparatus as recited in claim 2 further characterized in that:

25 said alignment members are forward and side alignment pedestals.

7. An apparatus as recited in claim 2 further characterized in that:

said alignment members are vertical standoffs.

30 8. An apparatus as recited in claim 1 further characterized in that:

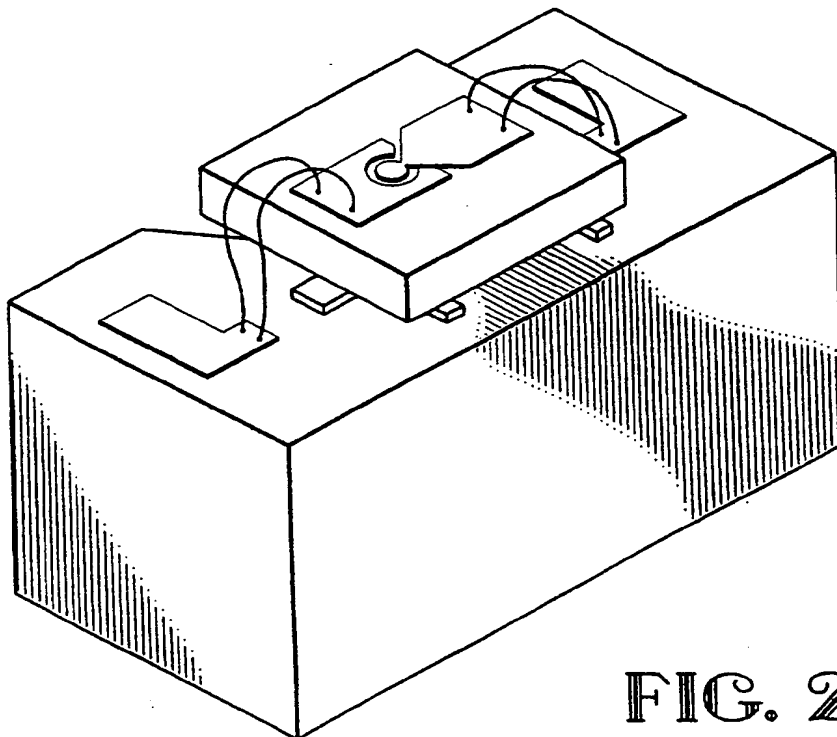
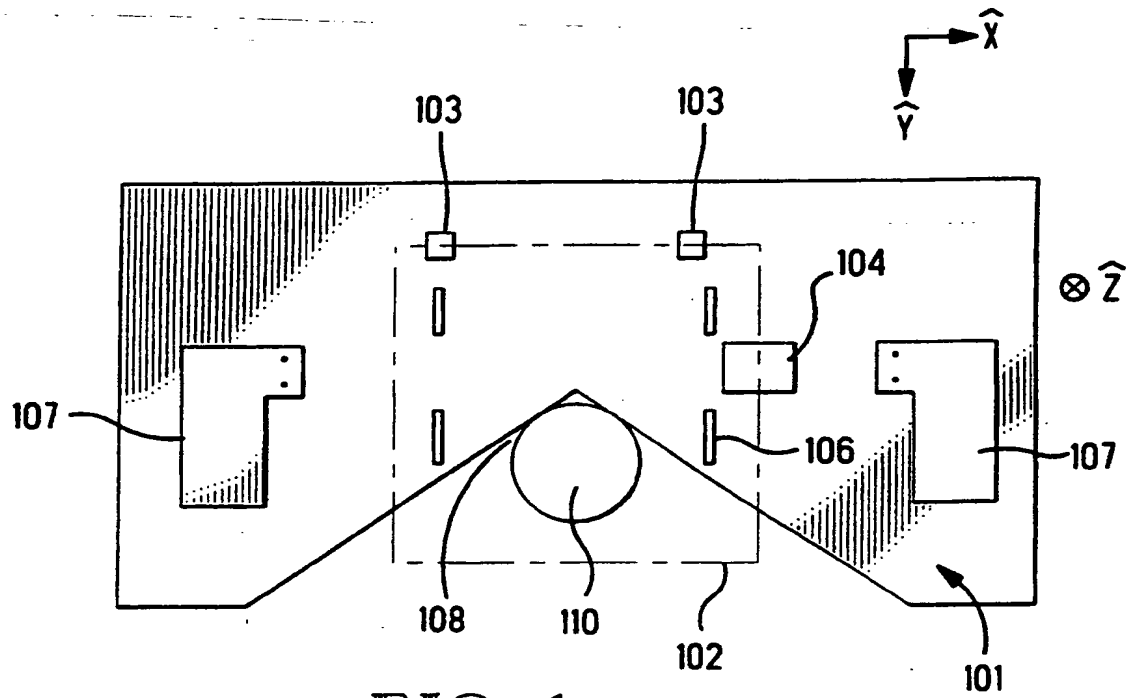
said optoelectronic device is a VCSEL.

9. An apparatus as recited in claim 1 further characterized in that:

said optoelectronic device is a photodetector.

The present invention relates to a simple but fundamentally different way of aligning optical fibers and devices on monocrystalline material. To this end, a passive alignment frame has an etched surface for receiving an optical fiber for attachment therein. Also disposed on the passive alignment frame are alignment pedestals and standoffs that are formed on the frame by reactive ion etching. The pedestals allow for ready and accurate placement and bonding of the device to be coupled to the fiber. The device and the fiber are aligned and coupled passively. In the preferred embodiment shown in Figure 2, the device and the fiber are bonded to the passive alignment frame which is then readily packaged without substantial limitation.

15



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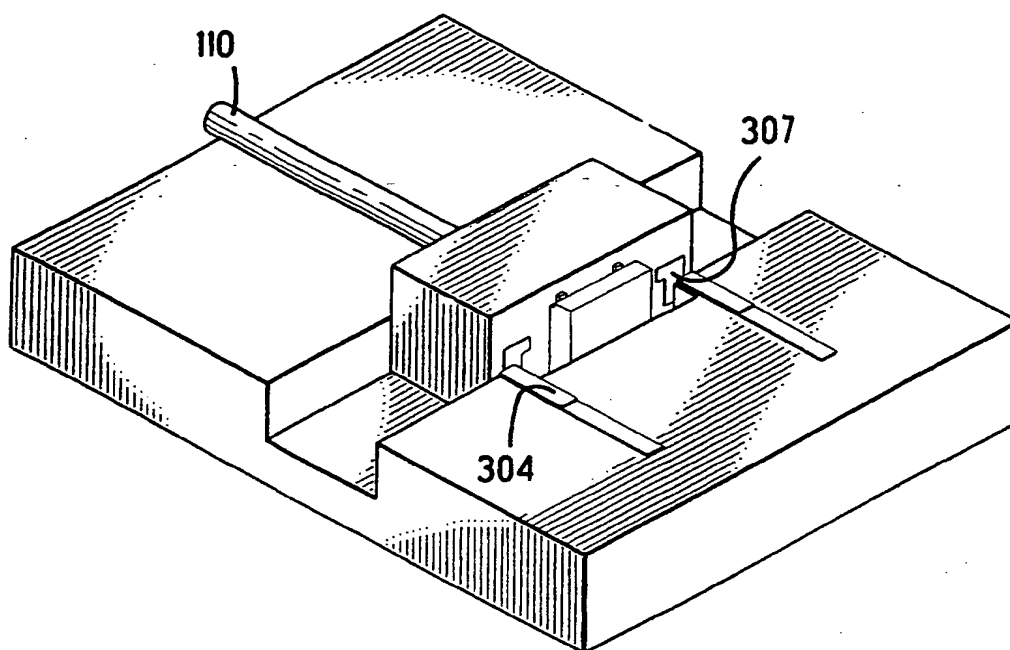


FIG. 3

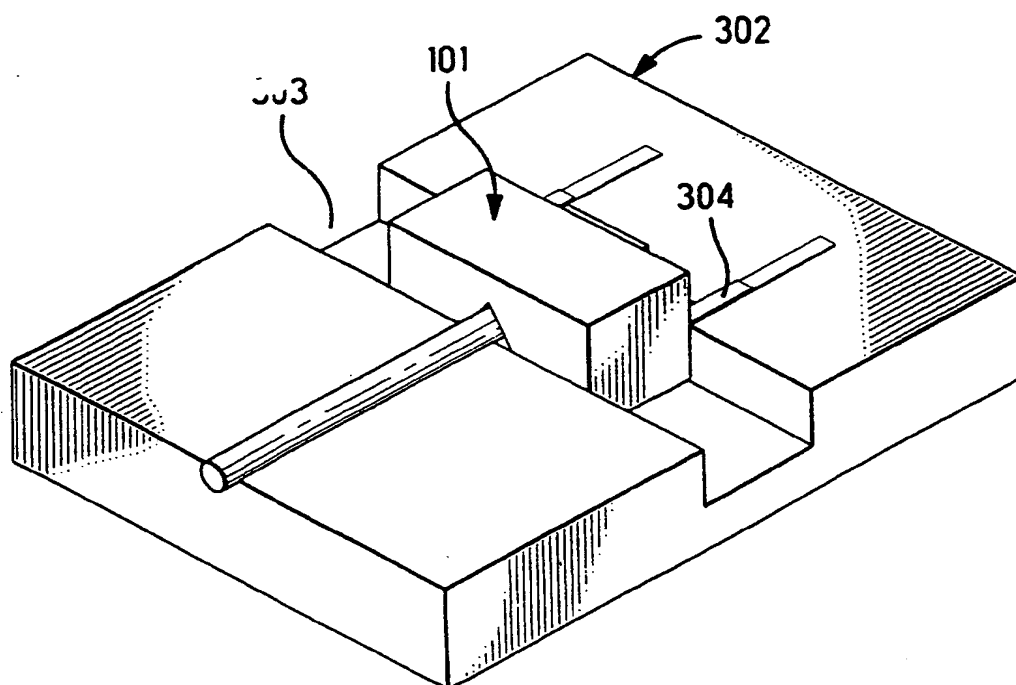


FIG. 4

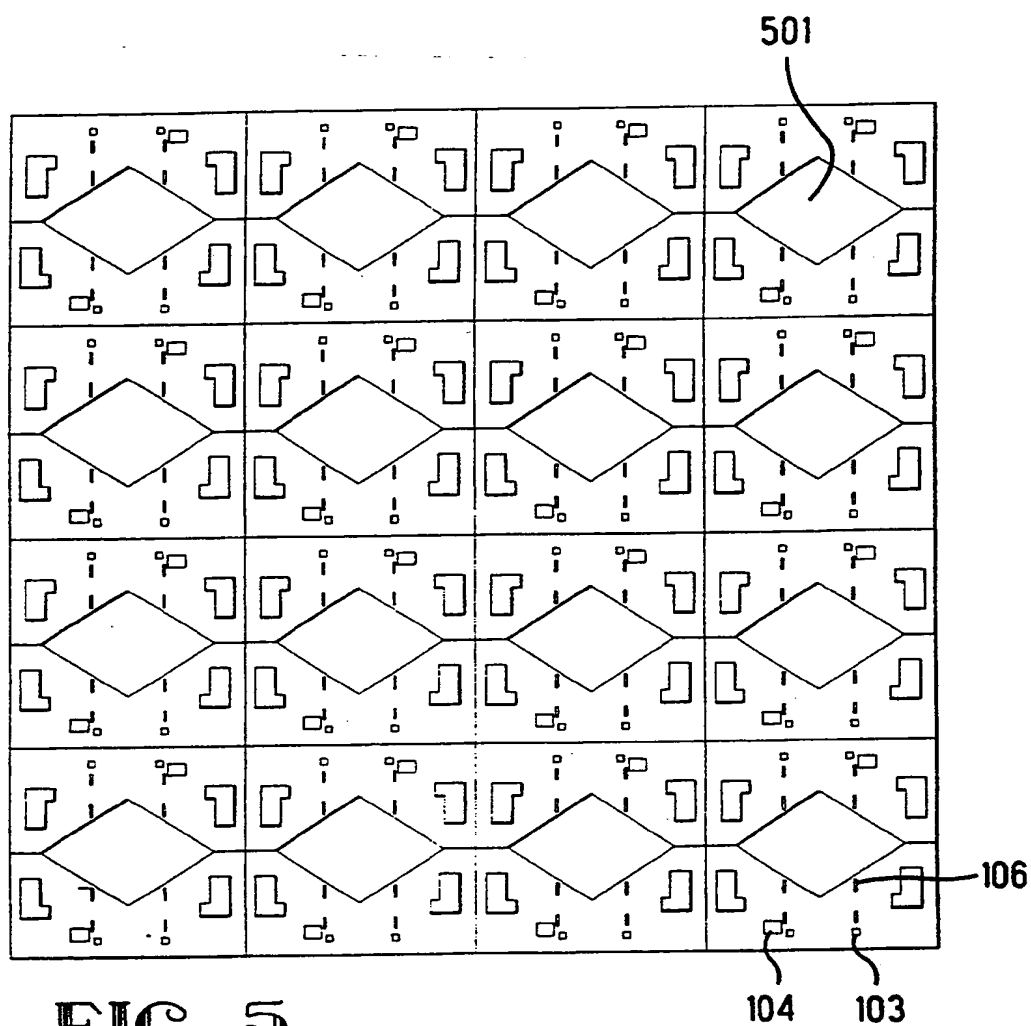


FIG. 5

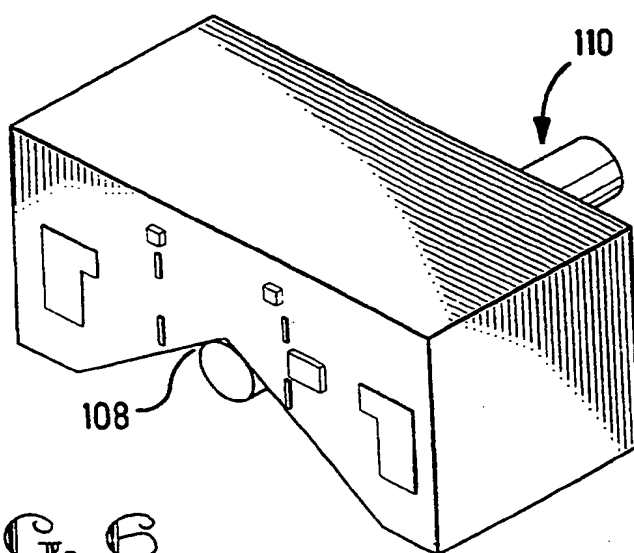
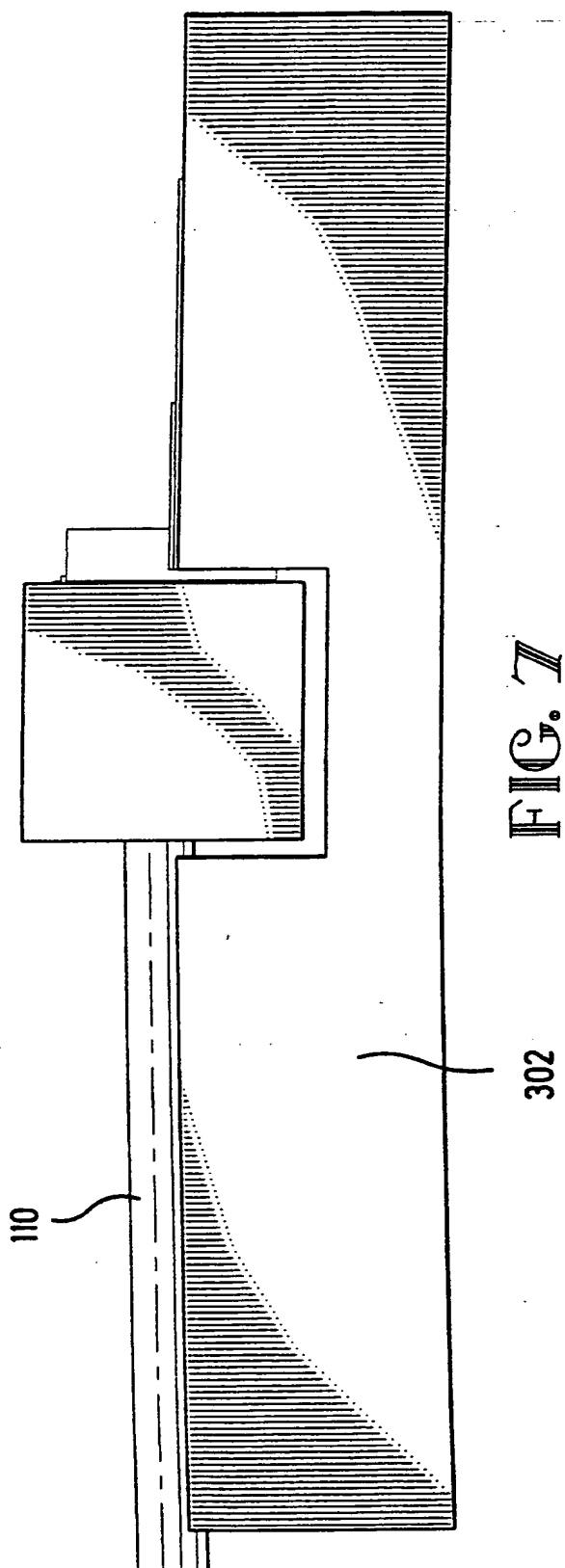


FIG. 6



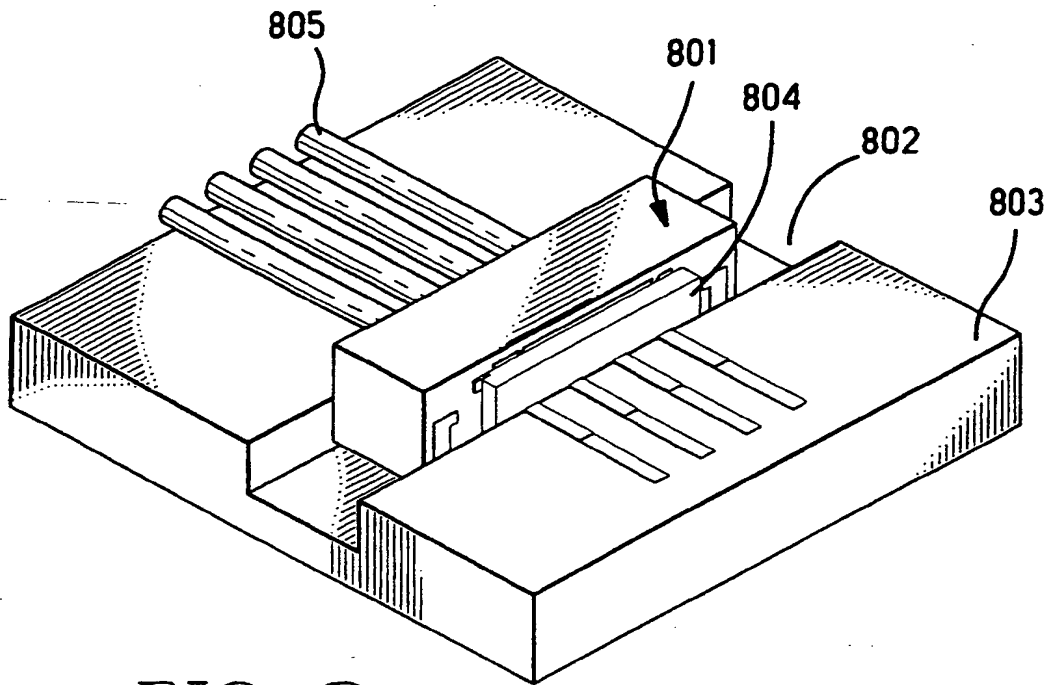


FIG. 8

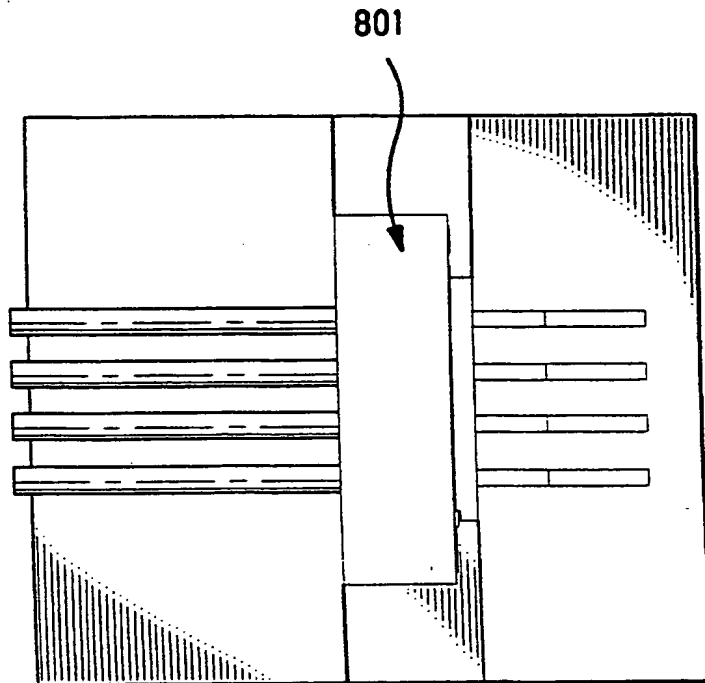


FIG. 9

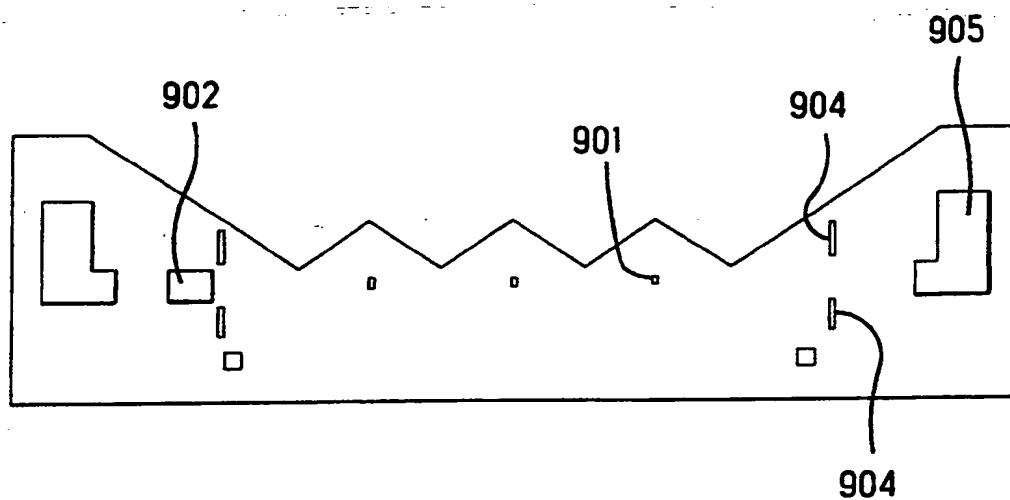


FIG. 10

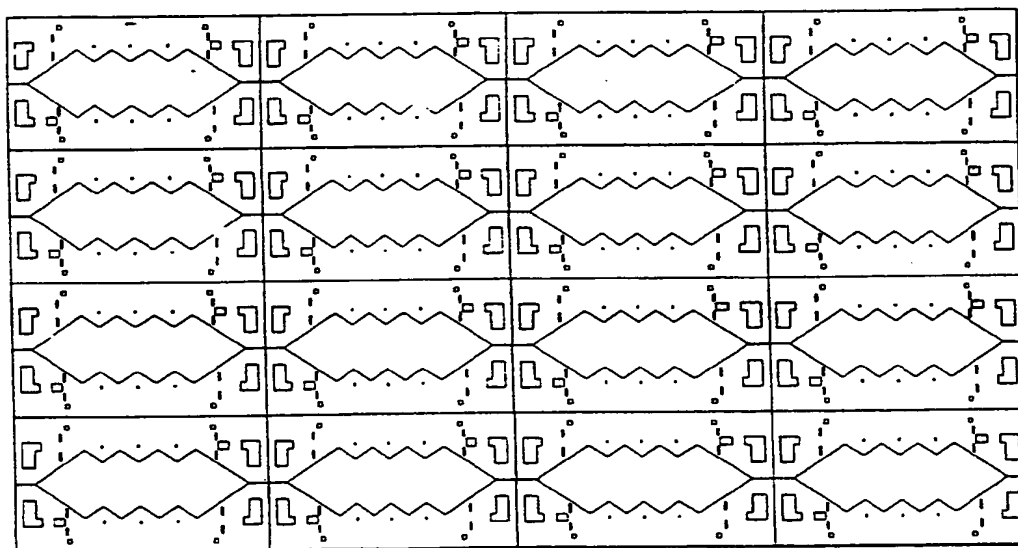


FIG 11

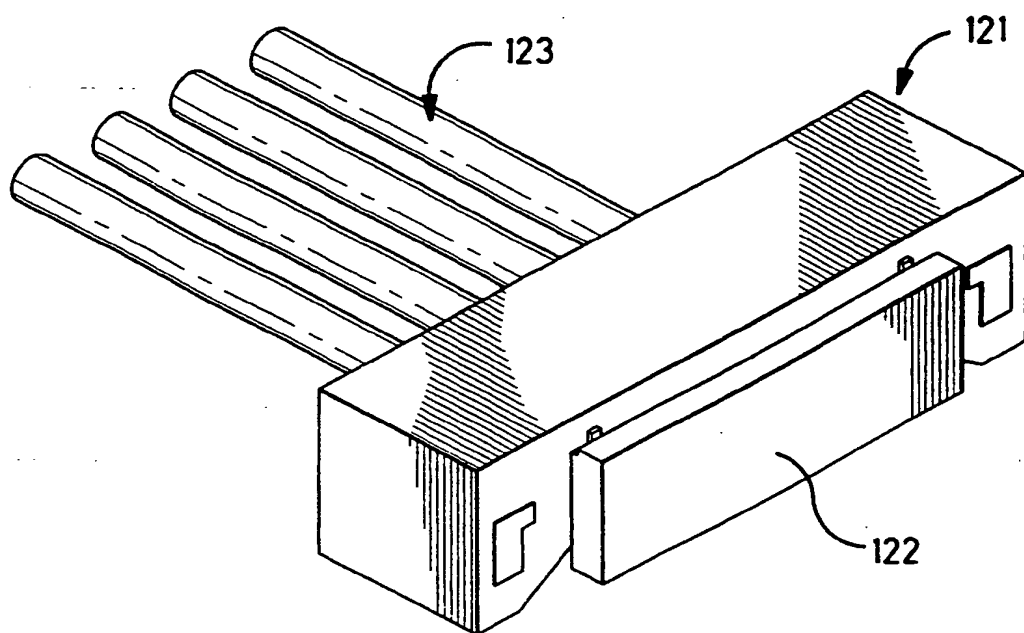


FIG. 12

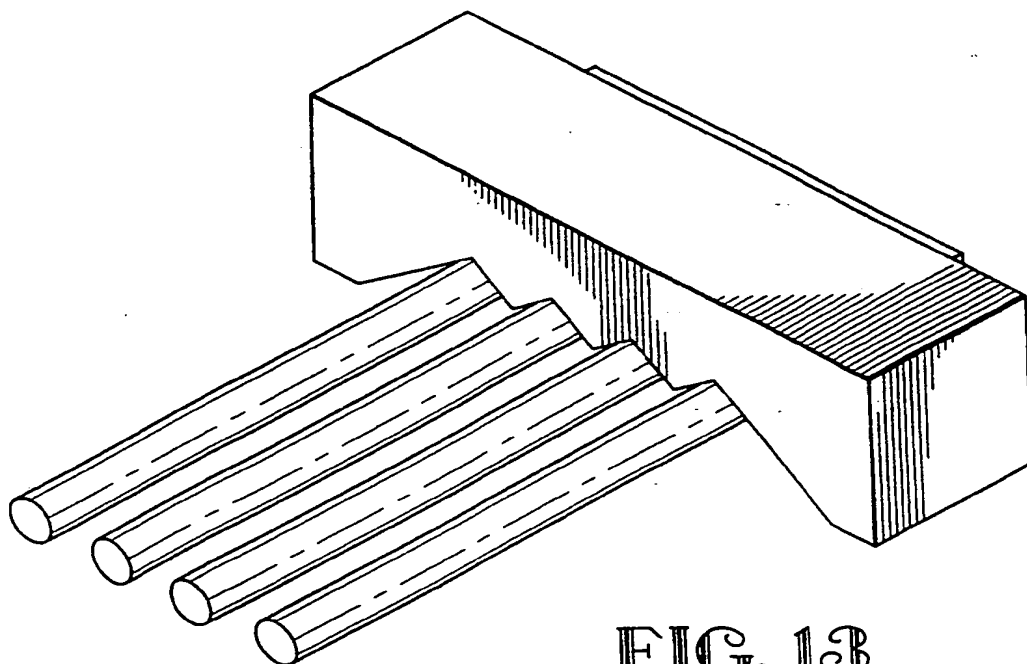


FIG. 13

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 96/10996

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G02B6/42

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 5, no. 30 (E-047), 24 February 1981 & JP,A,55 157277 (FUJITSU), 6 December 1980, see abstract	1-4,9
Y	---	5-7
Y	EP,A,0 532 469 (CENTRE SUISSE D'ELECTRONIQUE ET DE MICROTECHNIQUE) 17 March 1993 see abstract; figure 2	5,6
Y	---	
Y	EP,A,0 304 118 (PLESSEY OVERSEAS) 22 February 1989 see column 4; figure 5	5,7
X	---	
	DE,C,43 01 236 (ANT NACHRICHTENTECHNIK) 17 March 1994 see page 3; figures 1-4	1,3,4,9

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Date of the actual completion of the international search

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	<p>EP,A,0 226 296 (BRITISH TELECOMMUNICATIONS) 24 June 1987 see page 4 - page 5; figures 1-5 -----</p>	1,3,4,9

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 96/10996

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A-532469	17-03-93	CH-A- 685522	31-07-95
EP-A-304118	22-02-89	GB-A- 2208943	19-04-89
		DE-A- 3880234	19-05-93
		JP-A- 1140104	01-06-89
		US-A- 4892377	09-01-90
DE-C-4301236	17-03-94	EP-A- 0607880	27-07-94
EP-A-226296	24-06-87	DE-A- 3687063	10-12-92
		DE-D- 3689537	24-02-94
		DE-T- 3689537	28-04-94
		EP-A- 0223414	27-05-87
		EP-A- 0219356	22-04-87
		EP-A- 0219357	22-04-87
		EP-A- 0219358	22-04-87
		EP-A- 0219359	22-04-87
		WO-A- 8702474	23-04-87
		WO-A- 8702518	23-04-87
		WO-A- 8702472	23-04-87
		WO-A- 8702476	23-04-87
		WO-A- 8702475	23-04-87
		WO-A- 8702470	23-04-87
		JP-B- 6090329	14-11-94
		JP-T- 63501600	16-06-88
		JP-B- 8027432	21-03-96
		JP-T- 63501382	26-05-88
		JP-B- 7069520	31-07-95
		JP-T- 63501383	26-05-88
		JP-B- 7007149	30-01-95
		JP-T- 63501384	26-05-88
		JP-T- 63501393	26-05-88
		JP-B- 2514343	10-07-96
		JP-T- 63501385	26-05-88
		US-A- 4867532	19-09-89
		US-A- 4854658	08-08-89
		US-A- 4802727	07-02-89
		US-A- 4825262	25-04-89
		US-A- 4871244	03-10-89
		US-A- 4846930	11-07-89

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 96/10996

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A-226296		US-A- 4896936	30-01-90
		CA-A- 1333452	13-12-94
		CA-A- 1284372	21-05-91
		CA-A- 1271552	10-07-90
		CA-A- 1277525	11-12-90
		CA-A- 1278910	15-01-91
		CA-A- 1276781	27-11-90
